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GB A 2128006   GB 1541566
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(58) Field of search
G4H

(54) **Display systems for operation by persons of limited controllable mobility**

(57) An operator-controlled display system, particularly for disabled persons, comprises a plurality of electrical switches, the actuating elements of which are closely grouped in a pattern so that the switches may be operated, e.g. by the user's tongue, either singly or in selected combinations. The switches control a visual display through an interface and a microcomputer, operation of a particular switch or combination of switches producing an effect in a portion of the visual display, the position of which effect is related to the position of the switch or switches in the aforesaid pattern. The user may thus select a particular area or point on the display by operating the appropriate switches.
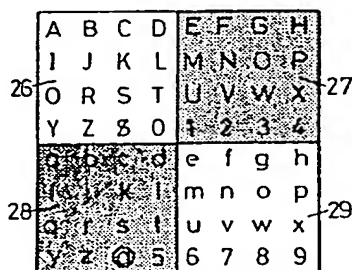
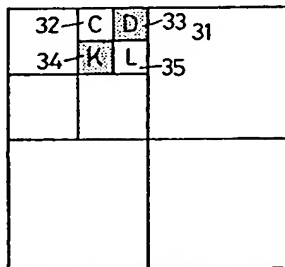a) INITIAL CONFIGURATION
FIG.6
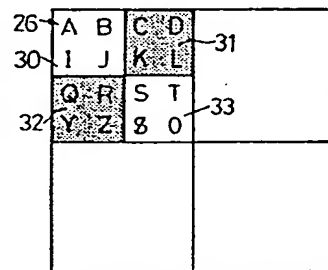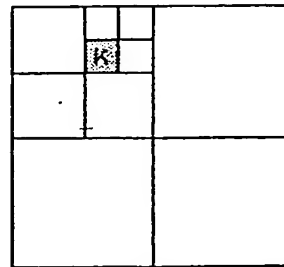

b) AFTER ONE KEYSTROKE
FIG.7

c) AFTER TWO KEYSTROKES
FIG.8

d) AFTER THREE KEYSTROKES
FIG.9

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FIG.1

FIG.3

17   18

16

FIG.2

14   15

17   18

16

FIG.4

17   18   16

19   20

10

12

13   11

SWITCH
UNIT

21

INPUT
INTERFACE

22

COMPUTER/LOGIC ARRAY

23

VISUAL
DISPLAY

24

OUTPUT
INTERFACE

25

FIG.5

DEVICES
TO BE
CONTROLLED

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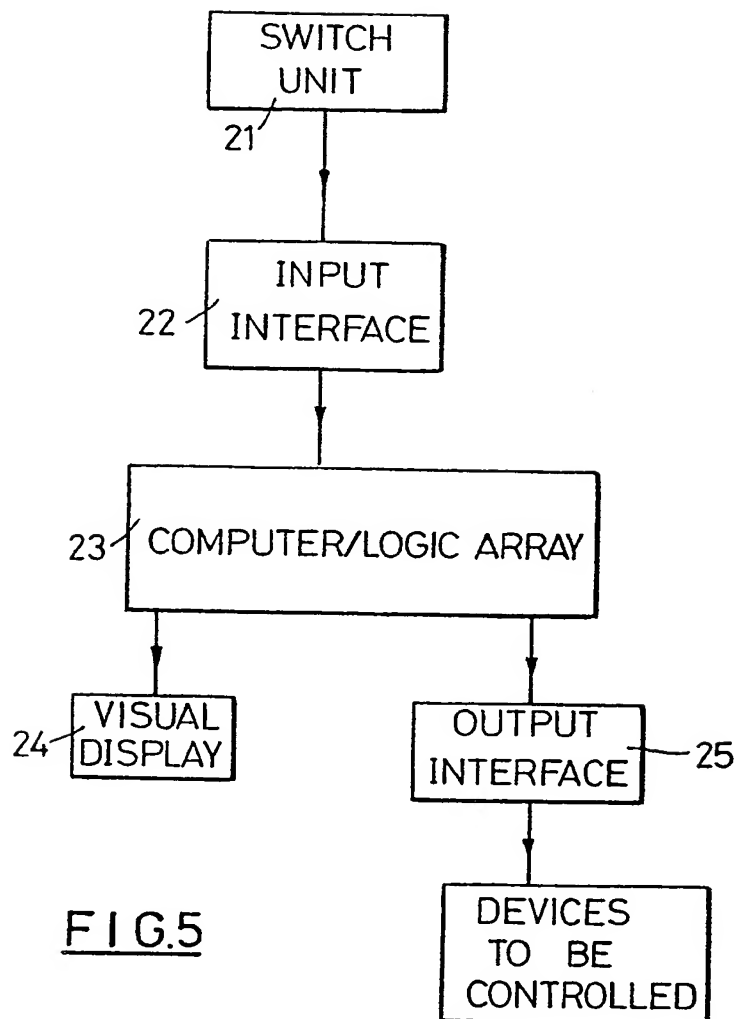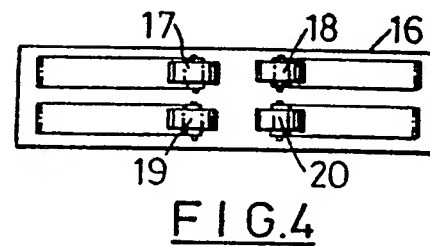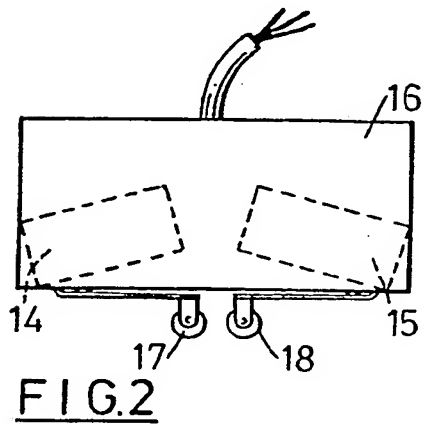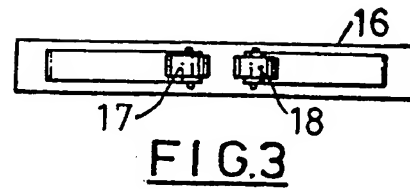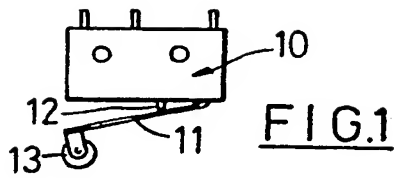
A B C D	E F G H
I J K L	M N O P
O R S T	U V W X
Y Z 8 0	1 2 3 4
a b c d	e f g h
f j k l	m n o p
q r s t	u v w x
y z @ 5	6 7 8 9

26 27 28 29

a) INITIAL CONFIGURATION

F I G.6

26 → A B C D — 31
30 → I J K L
32 → Q R S T — 33
Y Z 8 0

b) AFTER ONE KEYSTROKE

F I G.7

32 → C D ← 33 31
34 → K L — 35

c) AFTER TWO KEYSTROKES

F I G.8

K

d) AFTER THREE KEYSTROKES

F I G.9

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┌──────────┐              ┌──────────────┐
│  INPUT   │              │              │
│  DEVICE  │─────────────▶│   COMPUTER   │
│          │              │              │
└──────────┘              └──────────────┘
                                 │
                                 │
                                 ▼
                          ┌──────────────┐
                          │    OUTPUT    │
                          │  INTERFACE   │
                          └──────────────┘
                                 ┊
                                 ┊
                                 ▼
┌──────────────┐    128    ┌──────────────┐
│              │◀──LINES───│              │
│    SCREEN    │   OUT     │   DECODER    │
│              │           │              │
└──────────────┘           └──────────────┘
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F I G.10

SPECIFICATION

Improvements in or relating to display systems for operation by persons of limited controllable mobility

5 The invention relates to display systems for operation by persons of limited controllable mobility, and 5
particularly for operation by physically disabled people.
Systems are known for enabling disabled people to communicate and/or carry out operations, wherein a
visual display sets out an array of options and the operator controls selection of a particular option by
controlling movement of an indicator, such as a cursor, over the array. In a common system for
10 communication the visual display includes a list of messages which are illuminated or otherwise indicated in 10
sequence and the operator selects a particular message by moving an indicator step-by-step until it reaches
that message. Reaching of the message by the indicator may also be arranged to operate, or enable
operation of, an operating mechanism with which the message is associated. For example, if the message
reads "switch on light", this may either be a simple request to another person to carry out the operation
15 required, or selection of the operation on the display may actually be arranged to switch on the light. 15
However, such known arrangements suffer from the disadvantage that, in practice, only a limited number
of predetermined options may be permitted, and the system does not allow the user to communicate on a
subject not provided for by the predetermined messages.
Alternative arrangements have therefore been proposed for enabling a disabled person to operate a
20 keyboard, such as a typewriter or microcomputer keyboard, in order to widen the range of communication. 20
However, the systems for operating the keyboard are elaborate and laborious to operate and may still be
beyond the capabilities of certain classes of disabled person. This is due to the necessity of, through some
sort of control system, actuating a different key of the keyboard for each letter or symbol to appear on the
screen or paper. The present invention sets out to provide an improved operator-controlled display system
25 suitable for operation, without considerable effort, by persons of limited controllable mobility, such as 25
disabled persons.
According to the invention there is provided an operator-controlled display system comprising a plurality
of electrical switches, the actuating elements of which are closely grouped in a pattern so that the switches
may be operated either singly or in selected combinations, and an electrically actuated visual display
30 controlled by said switches in such manner that the operation of a particular switch or combination of 30
switches produces an effect in a portion of the visual display, the position of which effect is related to the
position of the switch or switches in the aforesaid pattern.
Preferably the switches are closely grouped in such manner that they may be operated by the tongue of
the operator.
35 Since the effect on the visual display is related to the positions of the switches, any part of the display may 35
be selected at will by the operator by actuation of the appropriate switches, without the necessity of moving
a cursor or other indicator across all parts of the screen in succession until the required position is reached.
Preferably the switches are coupled to the visual display through a microcomputer which is programmed
to control the visual display in accordance with the operation of the switches.
40 Preferably there is direct correspondance between the position, in the pattern of switches, of the switch or 40
switches operated and the position on the visual display of the visual effect of such operation.
The visual display may comprise a main array of items of information, so that a single item may be
selected from the array by operation of one or more appropriate switches, the item, when selected, being
visually indicated on the display, for example by blanking out non-selected items. Each item in the main
45 array may comprise a sub-array of further items of information, the arrangement of items in each sub-array 45
corresponding to the arrangement of items in the main array, such that, once a sub-array has been selected,
further operation of one or more switches selects an item in the selected sub-array in accordance with the
position of the switch or switches operated.
There may thus be provided a plurality of levels of sub-arrays and, under microcomputer control, there is
50 virtually no limit to the total number of items from which selection can be made by having sufficient levels of 50
sub-arrays. All the items of information may be displayed on the visual display initially and the selection
made by selecting successively smaller areas of the main array. Alternatively, once a sub-array has been
selected it may be enlarged to take over substantially the whole of the visual display so that the next
sub-array within it may be selected.
55 The microcomputer may be programmed to control operations other than the aforesaid effects on the 55
visual display upon operation of certain of said switches or combinations thereof. For example, operation of
a switch or a combination of switches may be arranged to produce an effect on the visual display which is
dependent on which particular item was previously selected from the aforesaid arrays. For example, where
each item consists of a letter of the alphabet or other symbol, the arrangement may be such that once a
60 particular letter or symbol has been selected a further switch operation prints the letter or symbol at a 60
required position on the visual display and/or a hard copy print-out.
Alternatively or additionally, the microcomputer may be interfaced with external operating devices which
are controlled by operation of a switch or a combination of switches, the nature of the control being
dependent on the item previously selected by the operator from the visual display. For example, the item in
65 the array on the visual display may comprise the alternative positions of a steering member on a wheelchair 65

so that once a particular desired position has been selected visually further switch operation actually carries out the selected steering movement. It will be appreciated that this is applicable to virtually any type of control for any type of electrically operated device.

Although the switch assembly may be of any suitable type depending on the particular disability of the
5   operator, it is particularly desirable, as mentioned above, that the switch assembly may be operated by the tongue of the operator. There are various known types of mouth-operated switches. For example, a common type is a suck/blow switch operated through a plastics tube, but this has the disadvantage that it is slow and can cause hyperventilation and it is also difficult to control a plurality of switches by this method. There are also switches which are located within the user's mouth behind the teeth in the upper palate. Such a switch
10 however has the disadvantage that it can be uncomfortable and irritating and can promote dribbling.

Accordingly, the present invention also sets out to provide, in another aspect thereof, an improved form of switch assembly which is particularly suitable for use with the display system referred to above, but which is also capable of wider application.

Thus the invention provides a switch assembly for operation by the tongue of an operator, and comprising
15 a plurality of microswitches mounted on a support and with the actuating elements thereof closely grouped in a pattern, the support being mounted on a carrier whereby the switch assembly may be supported externally of the mouth of the operator and thus operated by protrusion of the tongue from the mouth.

The carrier may be adapted for mounting on the body of the user in a manner to hold the switch assembly adjacent the user's mouth.
20 Such an arrangement is more convenient and more comfortable to use than known arrangements since the switch assembly may be readily displaced from the user's mouth when not required and the user may also turn his head away from the assembly. Furthermore, the grouping of a plurality of microswitches allows operation of a display system of the kind referred to above.

The following is a more detailed description of various embodiments of the invention reference being
25 made to the accompanying drawings in which:

Figure 1 shows diagrammatically a microswitch suitable for use in the invention,

Figures 2 to *4* show the switch assemblies incorporating such microswitches,

Figure 5 is a diagrammatic representation of a display system according to the invention,

Figures 6 to *8* represent views of one form of visual display at different stages during operation of the
30 system, and

Figure 9 is a diagrammatic representation of an alternative form of system.

Figure 1 shows a basic type of known microswitch suitable for use in a tongue switch according to the invention. The microswitch comprises a main body 10 on which is mounted an angled lever arm 11 which operates a plunger 12. A small plastics roller 13 is mounted on the free extremity of the lever 11.
35 Referring to Figure 2, to provide the tongue-operated switch unit a plurality of microswitches such as 14 and 15 are mounted within a plastics casing 16, the main bodies of the microswitches being angled within the casing so that the lever arms on the two switches are brought into line and the rollers 17 and 18 of the switches are adjacent one another.

Figure 3 shows an arrangement with just two microswitches whereas Figure 4 shows an arrangement with
40 four microswitches within the casing, the operating rollers 17, 18, 19 and 20 of the microswitches being grouped together.

It will be appreciated that any other suitable number of microswitches may be mounted within the casing provided that their operating rollers are grouped sufficiently close together in a pattern as to enable the switches to be operated separately or in various combinations by the tongue of the operator.
45 It is found in practice that the distance between adjacent rollers should be approximately 0.75 cm to allow the tongue to press the microswitches singly or in combinations of two.

To support the switch unit, the casing 16 is mounted on a carrier which locates the unit adjacent the mouth of the operator so that the switches may be operated by protruding the tongue slightly from the mouth and engaging the appropriate switch or combination of switches. For example, the switch unit may be mounted
50 on a framework mounted on a fixed structure adjacent the operator's position on some component which moves with the operator, such as a headpiece, helmet, or movable chair. Alternatively, the frame may be supported on the shoulders and/or torso of the user in the manner of a mouth-organ holder.

Although the tongue switch described above may be used to control any sort of elctrically actuated device, it is particularly suitable for use in a display system of the kind previously referred to and such a display
55 system will now be described in greater detail by way of example.

Referring to Figure 5, the switch unit 21 is connected via a computer input interface 22 to a microcomputer or logic array 23 which is connected to a visual display 24 and may also be connected through an output interface 25 to other devices to be controlled. The switch unit 21 is preferably a tongue-operated switch unit of the kind described in relation to Figures 1 to 4 and having any suitable number of microswitches,
60 although, depending on the disability or other requirements of the user, other forms of switch unit could be used such as switch units operated by the fingers or other limbs of the user.

The input interface 22 preferably contains opto-isolators for isolating the switch unit from high voltages. However, in a system of this kind it is also possible to use very low voltage devices throughout.

The computer or logic array 23 may be a commercially available microcomputer but could also be a
65 purpose built hard-wired logic array.

The visual display 24 would normally be a cathode ray screen but could also be an LCD or LED display or a so called "head-up" display whereby the information is reflected from a transparent screen. The devices controlled by the output interface 25 may be of any kind, such as a printer, radio, light or head-up display. As previously mentioned, the switches in the switch unit 21 have their actuating elements closely grouped in a
5 predetermined pattern and the computer 23 is so programmed that information is displayed on the screen in   5
a configuration corresponding generally to the pattern of switches so that different portions of the display may be selected by operation of the appropriate switches or combinations of switches.

By way of example only there will now be described an arrangement for typing to the screen characters selected from 64 possible characters, using a tongue switch of the kind shown in Figure 4 incorporating four
10 microswitches.   10

Figure 6 shows the initial display on a portion of the T.V. screen, the display being divided into four quadrants 26, 27, 28 and 29, each quadrant including a sub-array of 16 characters in four rows of four. If the operator wishes to select, say, the character "K" he first selects the upper left-hand quadrant 26 containing this character by operating the upper left-hand switch 17 of the tongue switch shown in Figure 4. The
15 computer may be programmed so as then to blank out the unselected quadrants or, possibly, to highlight or   15
otherwise indicate the selected quadrant. In the former case the screen display is then as shown in Figure 7. The quadrant 26 is sub-divided (in a manner which may or may not be indicated on the screen, as required) into four sub-quadrants 30, 31, 32 and 33. The sub-quadrant containing the required character "K", that is the upper right-hand quadrant 31, is selected by a second key stroke, operating the upper right-hand
20 microswitch 18. The appearance of the screen is then as shown in Figure 8. The sub-quadrant 31 is divided   20
into four further sub-quadrants 32, 33, 34 and 35, and the operator then selectes the required lower left-hand sub-quadrant 34 by operating the lower left-hand microswitch 19 as a third key stroke, giving the screen appearance shown in Figure 8.

Once the required character has been selected by three key strokes in this manner, the program may be so
25 arranged as to effect automatic printing of the selected character to the screen at another location and/or to a 25
printer. Alternatively, a further operation of the tongue switch may be required to effect the actual printing to the screen and/or printer, for example operation of any two microswitches simultaneously.

The above arrangement is by way of example only and it will be appreciated that the principle can be extended to cover any suitable number and arrangement of microswitches and any suitable number and
30 arrangement of items of information on the screen, the only requirement being that, in order to facilitate   30
selection of particular sub-arrays on the screen, the configuration of the sub-arrays corresponds in some manner to the positioning of the microswitches.

The method can be expressed as a general formula for selecting a single option from n options using s switches. n and s are usually related by the formula $n = s^p$ where p is a positive integer. Thus, if four switches
35 or combinations of switches are being used, the display may contain 4^p items to begin with. At each key   35
stroke, p is reduced by one until it reaches zero at which point a single option has been chosen.

Thus, in the above described example we started with a display containing 64 ($= 4^3$) options. After one key stroke we are left with 16 ($= 4^2$) options; after two key strokes, four ($= 4^1$) options and after three key strokes there is one ($= 4^0$) option remaining. Thus we can chose any one out of 64 items with only three key strokes.
40 In general we can chose one out of n options with $\log_s n$ key strokes, where s equals the number of switches.   40

In any arrangement according to the invention the switches are arranged to some particular spatial configuration or pattern and the visual display has a corresponding spatial layout.

Thus, where the tongue switch comprises two microswitches arranged side-by-side the display may comprise simply two items side-by-side, for example a left-hand panel indicating "yes" and a right-hand
45 panel indicating "no".   45

Again, in a simple arrangement four switches arranged in a square may select any one of four items correspondingly arranged in a square on the display.

In a slightly more complex system a tongue switch incorporating four microswitches arranged as shown in Figure 4 may be arranged to select from 6 options arranged in two rows of three. In this case the four corner
50 items of the display may be selected by actuating the corresponding one of the four appropriate   50
microswitches. The upper centre of the six items is selected by operating the two upper microswitches 17 and 18 simultaneously, and the lower centre item of the display is selected by operating the two lower microswitches 19 and 20 simultaneously.

In any of the arrangements described above, each selected item may itself comprise a sub-array of a
55 further two, four or six options, as the case may be, the particular item of the sub-array being selected in   55
similar fashion by appropriate operation of the microswitches. It will be appreciated that any number of levels of selection may be provided. In some cases the number of possible options may be so great that they cannot all be initially displayed on the screen at the same time there is sufficient information on the screen to indicate in which portion of the screen the required item will eventually be found, the program may be so
60 arranged that at each selection of a sub-array the portion of the screen selected is shown over the whole   60
screen in greater detail to enable the next stage of selection to be made.

Although the rectilinear arrangement of switches and portions of the display is preferred as providing a readily observable correspondence between the positions of the switches and the elements of the display, it will be appreciated, that any other suitable pattern or configuration of the switches and elements of the
65 display may be provided.   65

The following is, by way of example, a computer program written in BBC Basic suitable for controlling a visual display in the manner described in relation to Figures 4 to 8. It should be stressed that this is by way of example only, and the program may be readily modified according to variations in the number of switches and in the required presentation of the display.

5   5

```
   1  MODE4
 170  scrnsize–40
 410  scrgap–scrnsize/2-5
 420  sp$–STRING$(scrgap+1," ")
 430  DIM arr4$(8,8)
 450  PROCread4
1000  REPEAT                )
1020  PROCfourchop          )  Main program loop
1040  PRINT TAB(10,10);i$;   )
1060  UNTIL FALSE           )
1999  END

6000  DEPROCfourchop    (Select one of the characters from the 8 × 8 array (in 3 stages)).
6005  hbase=5:vbase=hbase
6010  inc=2
6015  FOR chop=1 TO 3
6025  PROCdraw4
6032  PROCswtches
6035  IF insw=1 hbase=hbase–inc:vbase=vbase+inc
6036  IF insw=2 hbase=hbase+inc:vbase=vbase+inc
6040  IF insw=3 hbase hbase–inc:vbase=vbase–inc
6050  IF insw=4 hbase=hbase+inc:vbase=vbase–inc
6055  inc=inc/2
6060  NEXT chop
6062  iS=arr4$(hbase,vbase)
6065  ENDPROC

6070  DEFPROCdraw4    ('draw4' draws the display in the general case but is too slow in the first instance
                       when the 8 × 8 array is needed, hence use of 'frame4'. (See below)).
6075  PROCblank4
6080  IF chop=1 THEN PROCframe4:ENDPROC
6085  inc2=inc*2
6090  FOR I%=hbase–inc2 TO hbase+inc2–1
6095  FOR J%=vbase–inc2 TO vbase+inc2–1
6100  IF I%>=hbase AND J%<vbase PROCinvcol
6105  IF I%>=hbase AND J%>=vbase PROCtrucol
6110  IF I%<hbase AND J%>=vbase PROCinvcol
6115  IF I%<hbase AND J%<vbase PROCtrucol
6120  PRINT TAB(I%+scrgap,J%);arr4$(I%,J%);
6125  NEXT J%
6130  NEXT I%
6135  ENDPROC

6140  DEFPROCread4    (Read in contents of 8 × 8 array from DATA statement, see lines 6320 - 6355)
6142  RESTORE 6320
6145  FOR I%=1 TO 8
6150  READ t1$, t2$:t$=t1$+t2$
6155  FOR J%=1 TO 8
6160  arr4$(J%,I%)=MID$(t$,J%,1)
6165  NEXT J%:NEXT I%
6170  ENDPROC

6175  DEFPROCframe4    (Draw initial array onto screen)
6180  RESTORE 6320
6185  PRINT TAB(0,0)
6190  FOR I=1 TO 4
6195  PRINT sp$;
6196  PROCinvcol
6200  READ t1$:PRINT t1$;
6205  PROCtrucol
```

10   10
15   15
20   20
25   25
30   30
35   35
40   40
45   45
50   50
55   55
60   60
65   65

```
      6210  READ t2S:PRINT t2$
      6220  NEXT I
      6225  FOR I=1 TO 4
      6230  PRINT sp$;
   5  6240  READ t1$:PRINT t1$;
      6245  PROCinvcol
      6250  READ t2$:PRINT t2$
      6252  PROCtrucol
      6255  NEXT I
  10  6258  PROCtrucol
      6260  ENDPROC

      6265  DEFPROCblank4   (Blank out array before drawing subdivision)
      6270  FOR I=1 TO 8
  15  6275  PRINT TAB(), I);sp$;"......."
      6280  NEXT I
      6285  ENDPROC

      6290  DEFPROCtrucol   (Normal video)
  20  6295  COLOUR128:COLOUR1
      6300  ENDPROC

      6305  DEFPROCinvcol   (Inverse video)
      6310  COLOUR129:COLOUR0
  25  6315  ENDPROC

      6320  DATA A`}*,: $GH
      6325  DATA "I,-L",MN%P
      6330  DATA ?.-T,U£W%
  30  6335  DATA Y&01,234<
      6340  DATA abcd,efgh
      6345  DATA ijkl,mnop
      6350  DATA qrst,uvwx
      6355  DATA yz56,789>
  35
      9600  DEFPROCswitches   (Read switches at (in this case) the BBC's analogue port. Set 'insw' equal to 1,2,3,
                              or 4 according to which switch detected closed).
      9620  IF (ADVAL(0) AND 3)=0 AND ADVAL(1)>1000 AND ADVAL(2)>1000 GOTO 9620
      9640  IF (ADVAL(0) AND 3)=1 THEN insw=1
  40  9660  IF (ADVAL(0) AND 3)=2 THEN insw=2
      9680  IF ADVAL(1)<1000 THEN insw=3
      9700  IF ADVAL(2)<1000 THEN insw=4
      9710  IF (ADVAL(0) AND 3)<>0 OR ADVAL(1) 1000 OR ADVAL(2)<1000 GOTO 9710
      9720  ENDPROC
  45
```

Although the arrangement has been described using a tongue-operated switch of the kind shown in Figure 4, it will be appreciated that any other form of switch suitable for use by persons of limited controllable mobility may be employed, for example a touch switch or a switch operated by the foot, hand or any other part of the body. Also, the arrangement is not of course limited to use by persons having physical disability. There may be other reasons why a user has only limited controllable mobility; for example the pilot of an aircraft may have his major bodily movements entirely involved in controlling the aircraft, and in this case also a tongue-operated or other control may be suitable for a subsidiary purpose, such as changing a head-up display.

Although as previously described the visual display may be in the form of a cathode ray screen, many physically handicapped people also have defective eyesight and in view of this an extra large display may therefore be used. This could be done simply by having a transparent screen illuminated from behind by two different colours of lamp. The layout would be the same as used on the computer screen.

Because of the limited number of output lines from the computer a decoding circuit would be needed to decide which lamps were to be lit; and a suitable arrangement might be as shown in Figure 9.

CLAIMS

1. An operator-controlled display system comprising a plurality of electrical switches, the actuating elements of which are closely grouped in a pattern so that the switches may be operated either singly or in selected combinations, and an electrically actuated visual display controlled by said switches in such

manner that the operation of a particular switch or combination of switches produces an effect in a portion of the visual display, the position of which effect is related to the position of the switch or switches in the aforesaid pattern.

2.   A system according to claim 1, wherein the switches are closely grouped in such manner that they
5 may be operated by the tongue of the operator.

3.   A system according to claim 1 or claim 2, wherein the switches are coupled to the visual display through a microcomputer which is programmed to control the visual display in accordance with the operation of the switches.

4.   A system according to any of claims 1 to 3, wherein there is direct correspondence between the
10 position, in the pattern of switches, of the switch or switches operated and the position on the visual display 10 of the visual effect of such operation.

5.   A system according to any of claims 1 to 4, wherein the visual display comprises a main array of items of information, so that a single item may be selected from the array by operaton of one or more appropriate switches, the item, when selected, being visually indicated on the display,

15 6.   A system according to claim 5, wherein each item in the main array comprises a sub-array of further 15 items of information, the arrangement of items in each sub-array corresponding to the arrangement of items in the main array, such that, once a sub-array has been selected, further operation of one or more switches selects an item in the selected sub-array in accordance with the position of the switch or switches operated.

7.   A system according to claim 6, wherein, in use, all the items of information are displayed on the visual
20 display initially and the selection is made by selecting successively smaller areas of the main array. 20

8.   A system according to claim 6, wherein in use, once a sub-array has been selected it is enlarged to take over substantially the whole of the visual display so that the next sub-array within it may be selected.

9.   A system according to any of claims 1 to 8, and in which a microcomputer is programmed to control the visual display in accordance with the operation of the switches, wherein the microcomputer is also
25 programmed to control operations other than the aforesaid effects on the visual display upon operation of 25 certain of said switches or combinations thereof.

10.   A system according to claim 9, wherein operation of a switch or a combination of switches is arranged to produce an effect which is dependent on which particular item was previously selected from the aforesaid arrays.

30 11.   A system according to claim 10, wherein each item consists of a letter of the alphabet or other 30 symbol, the arrangement being such that once a particular letter or symbol has been selected a further switch operation prints the letter or symbol at a required position on the visual display and/or a hard copy print-out

12.   A system according to any of claims 1 to 11, wherein the microcomputer is interfaced with external
35 operating devices which are controlled by operation of a switch or a combination of switches, the nature of 35 the control being dependent on the item previously selected by the operator from the visual display.

13.   A system according to any of claims 1 to 12, wherein the plurality of electrical switches is provided by a switch assembly comprising a plurality of microswitches mounted on a support with the actuating elements thereof closely grouped in a pattern, the support being mounted on a carrier whereby the switch
40 assembly may be supported externally of the mouth of the operator and thus operated by protrusion of the 40 tongue from the mouth.

14.   A system according to claim 13, wherein the carrier is adapted for mounting on the body of the user in a manner to hold the switch assembly adjacent the user's mouth.

15.   An operator-controlled display system substantially as hereinbefore described with reference to the
45 accompanying drawings. 45